SENSOR INTEGRATION FOR URBAN APPLICATIONS

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ABSTRACT

Management of population centers in terms of infrastructure, environmental impact, and exposure to hazards is a multi-disciplinary activity which includes both social and physical sciences. An overview of selected recent activities in the area of remote sensing for addressing some of the data collection and analysis efforts for urban areas is presented here. Remote sensors which are used for urban monitoring are radar, lidar, multi and hyperspectral systems. Current remote sensing technologies provide a wide range of capabilities in terms of spatial and spectral resolutions which are appropriate for local and regional monitoring. The sensor examples which are used in this study are Intermap (x-band, 80 Mhz), JPL topsar (c-band, 40 Mhz), shuttle radar topography mission (SRTM, c-band, 10 Mhz), and the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) hyperspectral sensor.

Introduction

Geographical information of urban areas is useful for a number of applications such as the monitoring of urban change and growth, environmental impact studies, and hazard management and mitigation (Henderson, 1997; Dobson, 2000). Remote sensing of urban areas provides an efficient methodology for populating databases for geographical information systems (GIS). The information which are extracted from remote sensing data is dependent on the sensor resolution, and the sensing methodology. High resolution (sub meter) sensors are capable of providing detailed information in terms of urban land cover and 3 dimensional geometry. For example, high resolution stereo photography and light detection and ranging (LIDAR) systems provide detailed information regarding an urban environment which includes the shape of individual structures, road networks, and vegetation. This detailed information is gathered at a high cost in terms of data acquisition time, and post processing of the remote sensing data for GIS applications. As a result, the application of sub-meter remote sensing of urban areas is applicable for local analysis where the area of interest is of moderate size, i.e., a few square kilometers. Remote sensors with moderate resolution are able to map urban areas and provide information such as the urban bald earth topography, location of open and vegetated areas, and the built area density. For example, multi-spectral satellite systems such as LandSat, and SPOT sensors have been used for monitoring

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the land cover of large urban areas. Recently, interferometic synthetic aperture radar has been used to provide the three dimensional topography of urban environment. Remote sensing of urban areas at moderate spatial resolution (from a few meters to less than 100 meters) allows regional monitoring at a reasonable cost in terms of data acquisition and data processing.

Integration of remote sensing data of moderate resolution provides a methodology to increase the amount of information which can be extracted from an urban environment. For example multi-spectral data is used to enhance the interpretation of urban topography which is derived from interferometric measurements. In general the information provided by various remote-sensing technologies can be divided into two categories: Land cover, and three dimensional geometry. Multi-spectral and hyperspectral imaging and SAR measurements capture the land cover properties of a scene. The three dimensional geometry of a scene is measured by stereo optical, LIDAR and IFSAR (Gamba, 2000). Sensor spatial and spectral resolution determines the amount of information which is detectable from these measurements. At moderate resolution levels, integration of sensors which provide land cover information with those which provide three dimensional information enhances the capability to extract useful information regarding urban environment.

This paper illustrates the imaging capabilities of the interferometric synthetic aperture radar at pixel size levels ranging from 2.5 to 30 meters for urban mapping. Sensor integration capability is also demonstrated by an example where the hyper-spectral data (20 meter pixel size) is integrated with interferometric SAR data (5 meter pixel size) to extract the bald earth topography, location of vegetated areas, and the shape of dominant structures.

IFSAR Imaging of Urban Areas

Three dimensional (3D) geometry and land cover are among the types of information required for urban analysis. Current LIDAR systems are providing urban digital surface models with cm level accuracy. LIDAR high resolution data acquisition, however, is more time consuming in comparison with IFSAR. IFSAR systems provide a coregistered planimetric digital elevation model and a radar intensity image (Madsen, 1993). The IFSAR generated digital elevation model accuracy is typically in the meter level range for natural topography. For urban areas, the surface model accuracy degrades due to the presence of geometrical structures which cause shadowing and multi-path effects.

The information content of IFSAR images of urban areas is dependent on a number of radar system parameters such as radar operating frequency, radar bandwidth, and radar view angle. The effects of these parameters are shown using the radar image of a portion of the west side of Los Angeles which has been imaged using C-band (5.6 cm wavelength), 40 Mhz bandwidth, X-band (3 cm wavelength), 80 Mhz bandwidth, and C-band, 10 Mhz bandwidth radar systems. Fig. 1a shows an aerial view of the region. The radar images of the upper left corner of this area are shown in Fig. 1b, 1c. The pixel size of these images are 2.5 and 5 meters for the 80 Mhz and 40 Mhz systems, respectively. Fig. 2 shows a lower resolution c-band radar image of this area. Finer resolution provides detailed information of the built areas, while the coarse resolution image provides regional information.

Sensor Integration

Interpretation of remotely sensed data is enhanced by integrating information from various sensors. In urban areas, a multi- or hyperspectral sensor provides the land cover information such

as the location of areas covered by vegetation or by built environment such as buildings and roads (Roberts, 1997). This information is then used to interpret the corresponding digital elevation data which are captured by interferometric measurements. The multi-spectral data is segmented into physically descriptive classes, such as vegetation, building footprints, bodies of water, and features such as road network. This information is then used to extract geometrical information from the IFSAR digital elevation data. Fig. 3 shows the resulting visualization of an urban environment. Fig. 3a is a 20 meter resolution image of the west side of Los Angeles in the visible spectrum. The infrared portion of the sensor spectrum is used to provide a built environment data layer, Fig. 3b. Fig. 3c shows the background topography and dominant geometrical features of imaged area.

The accuracy of the resulting topography is dependent on the generated background topography as well as the accuracy of the height measurements by the interferometric system. The height reported for building tops are typically accurate since the radar backscattered signal is strong from such geometrical structures. The main sources of error in urban areas are due to layover effects where large structures affect the height measurements of the neighboring areas, and the shadowing effect, where some structures are not illuminated by the radar signal.

Conclusions

Remote sensing of urban areas, for local and regional applications, are feasible as a result of the availability of sensors with sufficient spatial and spectral resolution. These applications include change detection and hazard issues. Data Integration enhances the capability to extract information such as the location of vegetated areas, built environment density and cultural features.

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(a)

(b)   (c)

Figure 1.   Aerial images of west Los Angeles.   (a) Optical aerial photo, (b) x-band synthetic
Aperture radar intensity. 2.5 meter pixel, (c) c-band synthetic aperture radar. 5 meter
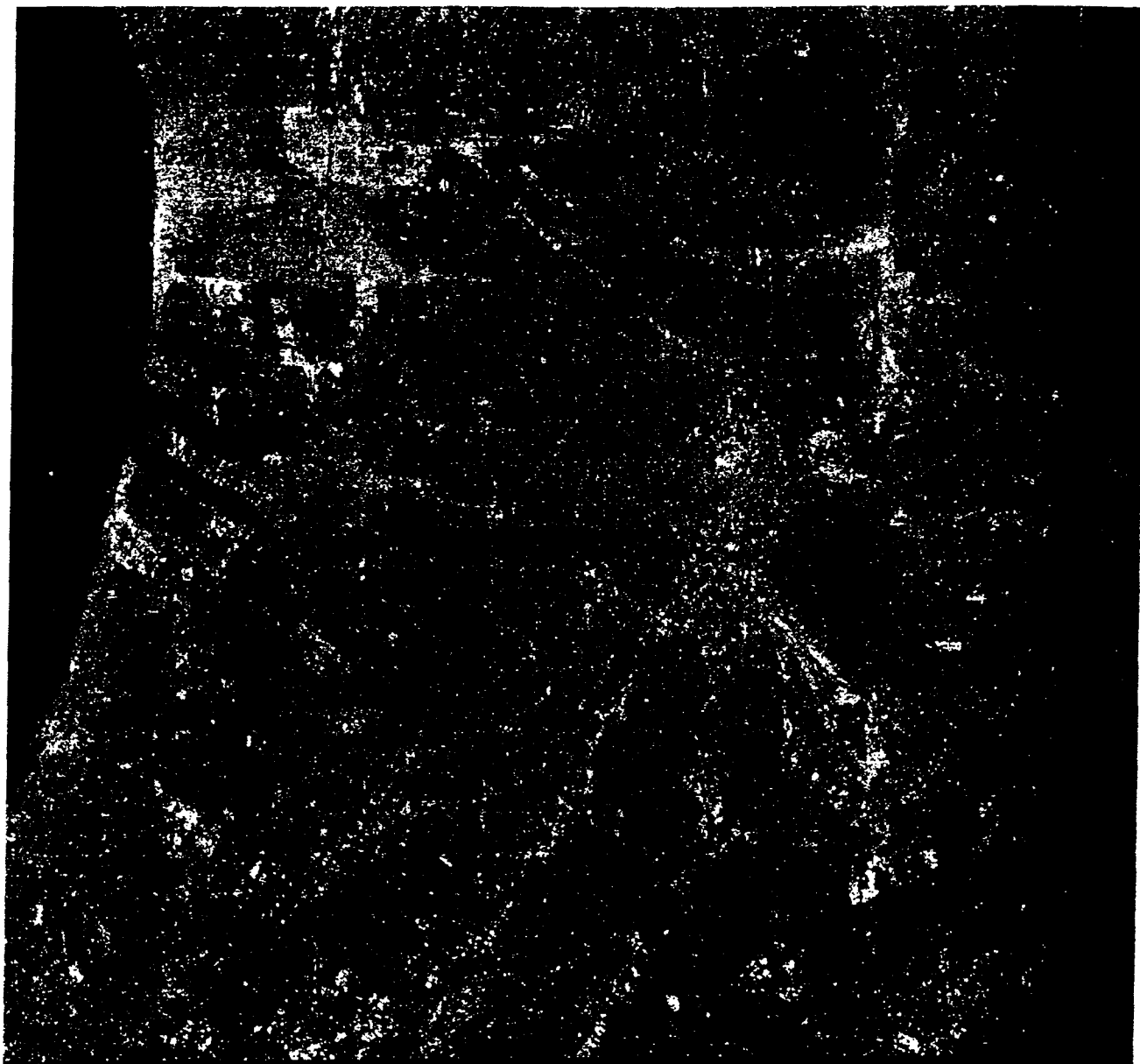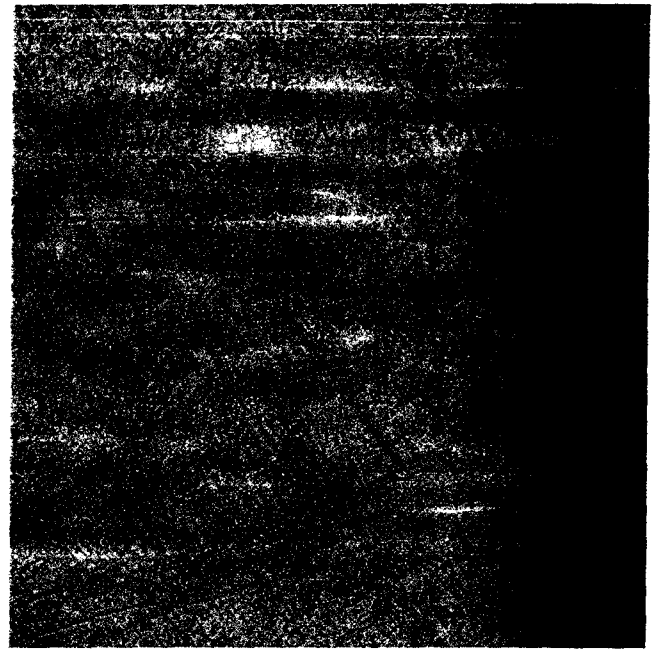pixel.

Figure 2. C-band. 10 Mhz. Synthetic Aperture radar image of Los Angeles from the shuttle radar topography mission.

Figure 3. Integration of Hyperspectral and Interferometric synthetic aperture radar data. (a) AVIRIS image (b) Corresponding derived vegetation-build area image, (C) visulaization of west of Los Angeles, including dominant strucutres.